

Zinc-nickel Plating for Propellant Actuated Devices (PADs)

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Development Branch



Making Sea Power 21 a Reality

Report Documentation Page			Form Approved OMB No. 0704-0188	
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Background

- Corrosion protection is critical to long term ejection seat reliability and operation
- Cadmium plating is used extensively in Propellant Actuated Devices (PAD) items

Pros ✓

- Good corrosion protection
- Thin enough for threads
- Good lubricity

Cons !

- Cadmium plater pool is drying up
- EPA regulates cadmium in air
- Cadmium toxic, carcinogen

Objectives

- Find a non-proprietary replacement, low toxicity, plating that provides corrosion protection \geq existing cadmium plating.
- Evaluate our low VOC painting system on the replacement coating.
- Assure that cadmium replacement doesn't induce hydrogen embrittlement.
- Qualify the replacement system.

Cadmium Replacement Selection

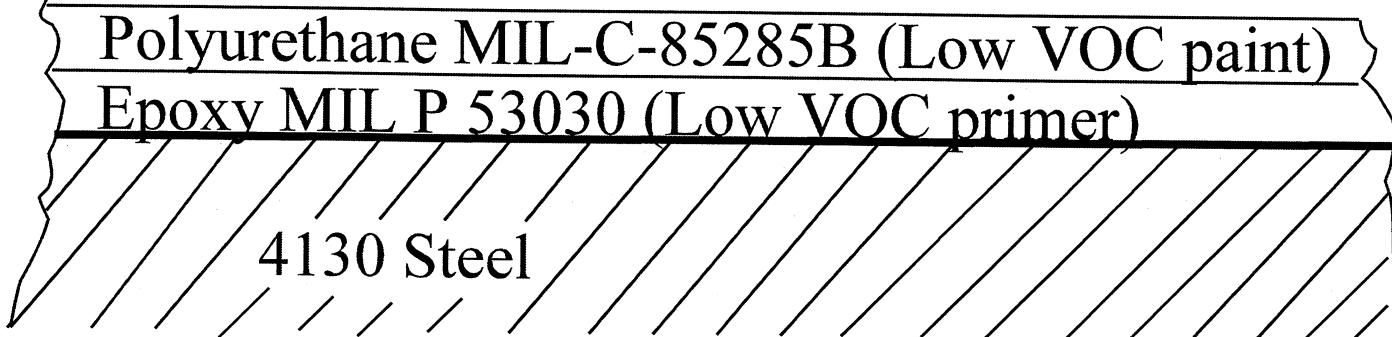
- Zn-Ni got favorable reviews in our extensive literature search
- Japanese automakers use Zn-Ni as a cadmium replacement
- Zn-Ni is *not* a proprietary coating

Overview

- Test results
- Process development
- Example components
- On-going work
- Lessons learned

1st Phase Test Panels: Cadmium

Previously Tested



Control Painted

Control Unpainted

Hex-Chromate Conversion
Cadmium Plate

Low VOC paint
Low VOC primer
Hex-Chromate Conversion
Cadmium Plate

4130/ 4340 Steel

4130 Steel

1st Phase Test Panels: Zinc-Nickel

Threaded

Teflon® water based gel

Zinc-High Nickel

Nickel Strike

4130/ 4340 Steel

Naval / Shipboard

Air Force / Internal

Hex-Chromate Conversion

Zinc-High Nickel

Nickel Strike

4130/ 4340 Steel

Low VOC paint

Low VOC primer

Phosphate Conversion

Zinc-Low Nickel

Nickel Strike

4130 Steel



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Test Matrix

Cadmium Replacement Test panel Test Matrix Overview.						
Tests	Control			Zinc - Nickel		
	Bare Metal	Cadmium Plated	Cadmium Plated Painted	Unpainted PADS	Painted	
				Chromate Conversion	Teflon Coated	
Each number represents (3) Test Panels						
a Working Properties			3			6
b Surface Appearance			Same above ↑			Same above↑
c Coating Anchorage			Same above↑			Same above↑
d Adhesion dry tape		2	3	4	5	6
e Adhesion Wet Tape			3			6
f Water Immersion			3			6
g Temperature Cycling		2	3	4	5	6
h Rain Test	1,1	2,2	3,3	4,4	5,5	6,6
i Humidity Test	Same above↑	Same above↑	Same above↑	Same above↑	Same above↑	Same above↑
j Salt Fog	Same↑	Same↑	Same↑	Same↑	Same↑	Same↑
k Chip Resistance		2	3,3	4	5	6,6
l Bend Test			3			6
0.39" x 3.94" x 0.035" 4340 Steel Strip Configuration						
Three test strips per Test Type						
m Hydrogen Embrittlement	7	8		9	10	11 Not Painted



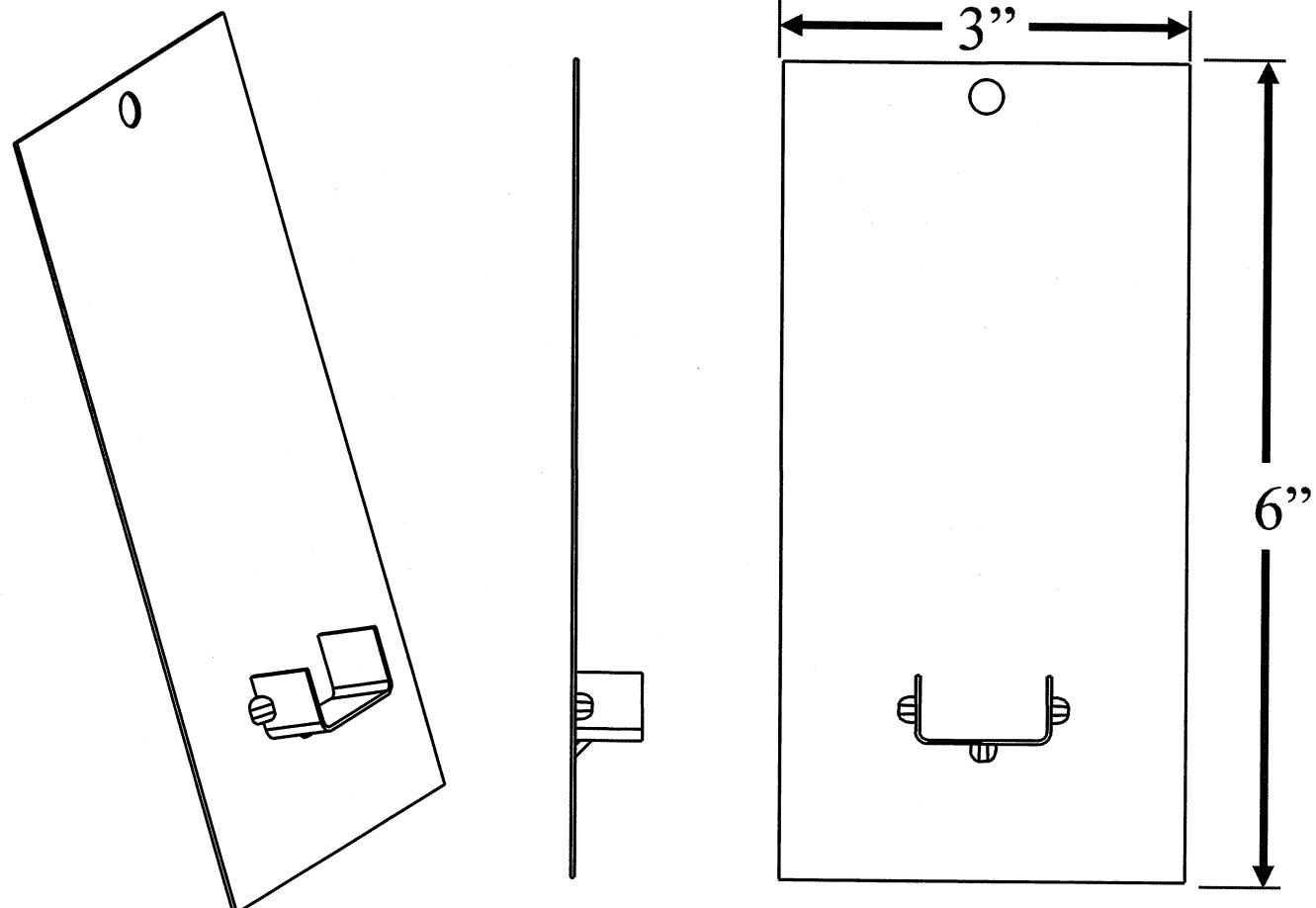
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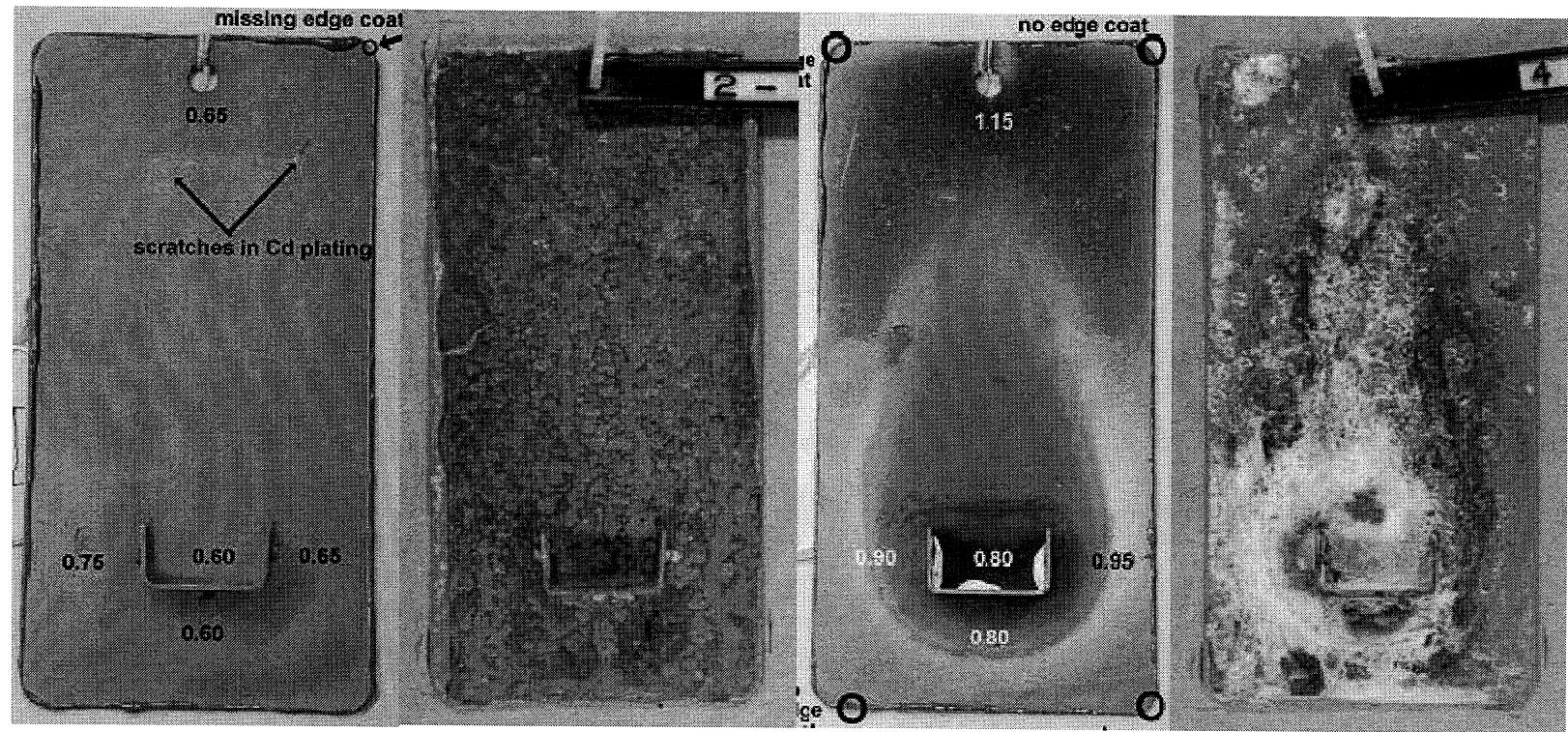
Test Matrix Legend

- a MIL-PRF-81352B Section 3.6
- b MIL-PRF-81352B Section 4.5.2
- c FED-STD-141C, Method 6304.1
- d ASTM D3359
- e FED-STD-141C, Method 6301.2
- f FED-STD-141C, Method 6011
- g MIL-P-83126A, Section 4.4.2.13
- h MIL-P-83126A, Section 4.4.2.14.1
- i ASTM D2247-99, and MIL-P-83126A,
Section 4.4.2.14.2
- j ASTM G85 ANNEX 5
- k ASTM D3170
- l ASTM D522 or ASTM D4145
- m Use Dipsol Gumm Ventures test for
BS EN 2831: 1993

1st Phase Test Panels: Environmental 4130 Steel



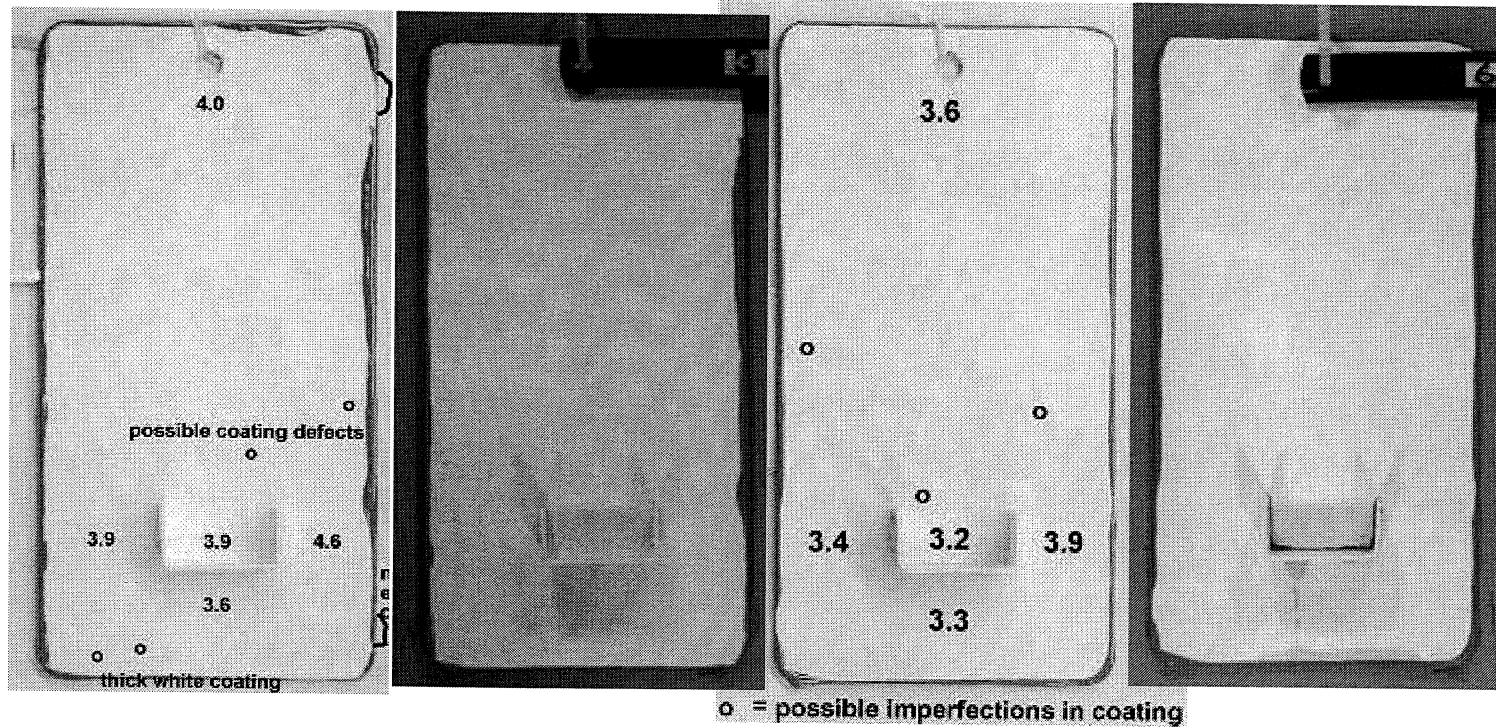
Results: 120 Day Salt Fog Test



**Cadmium Plated per
MIL-STD-870, Type II,
Class 1**

**Zinc - 9% to 13%
Nickel Plated per
ASTM B841-94, Class 1**

Results: 120 Day Salt Fog Test



**Cadmium Plated:
MIL-STD-870,
Type II, Class 1,**

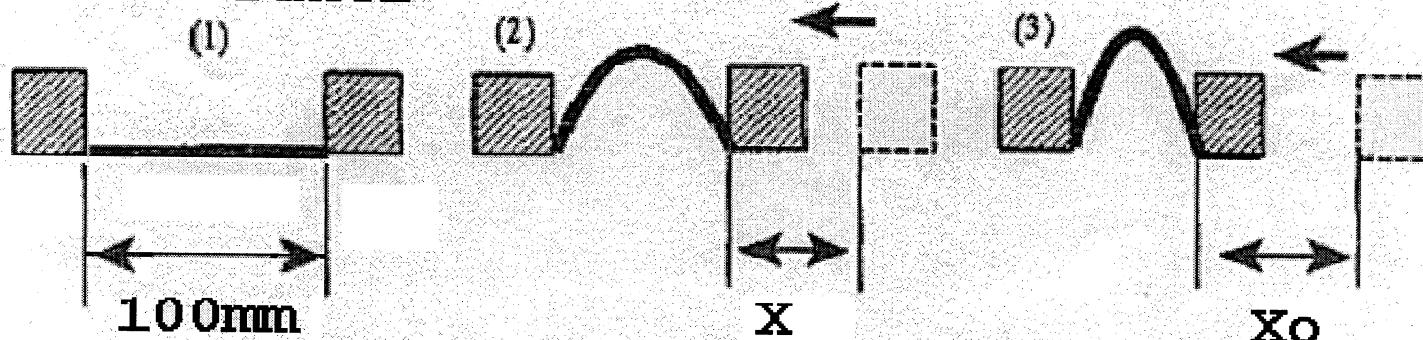
**Zinc - 5% to 7% Nickel per
ASTM B841-94, Class 1\ Zinc
Phosphate Conversion Coat**

Standard Prime and Paint After Plating

DIPSOL-GUMM Ventures

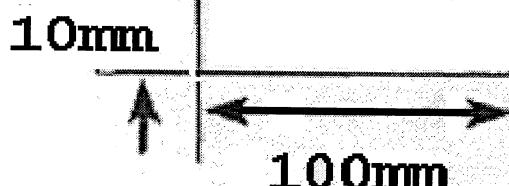
Hydrogen Embrittlement Testing

Test Panel



$$\text{Hydrogen Embrittlement (\%)} = 100 * (X_o - X) / X_o$$

↓ **Test Panel Dimensions**



Thickness: 0.9mm

Material: 4340 Steel

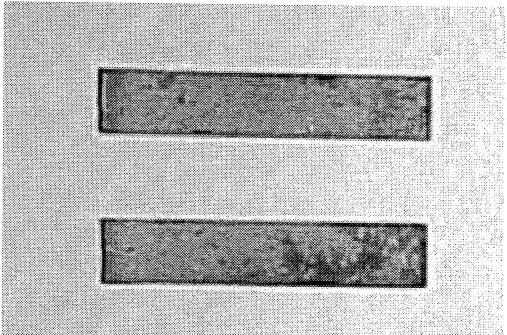
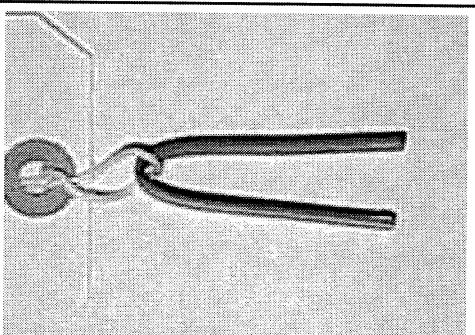
X_o: Standard unplated panel movement before break

X: Plated panel movement before break

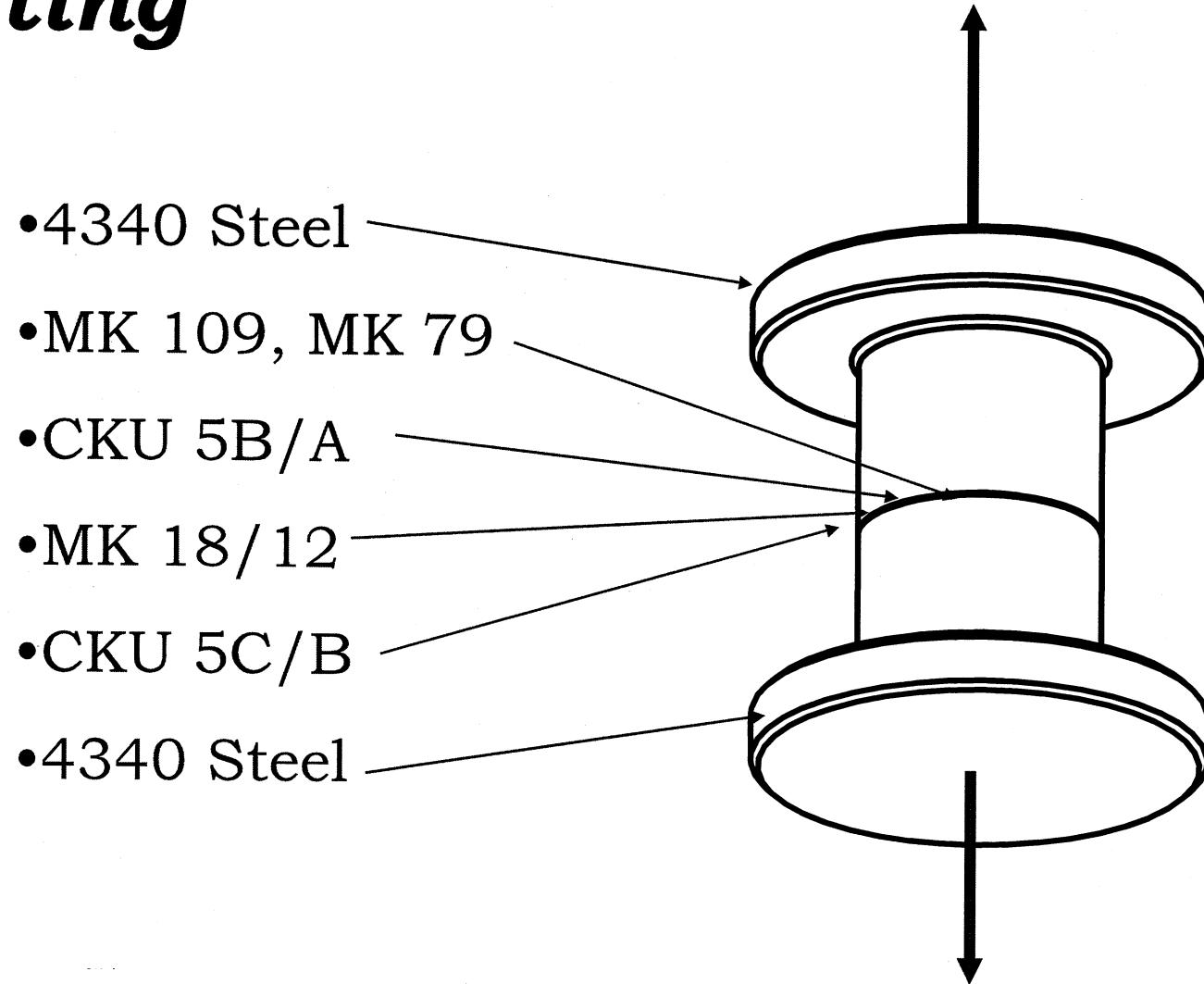
2nd Phase Hydrogen Embrittlement Test Specimens

- 1st Phase no stress relief after machining and heat treating
- 2nd Phase stress relieved per ASTM B 849-94 after heat treating

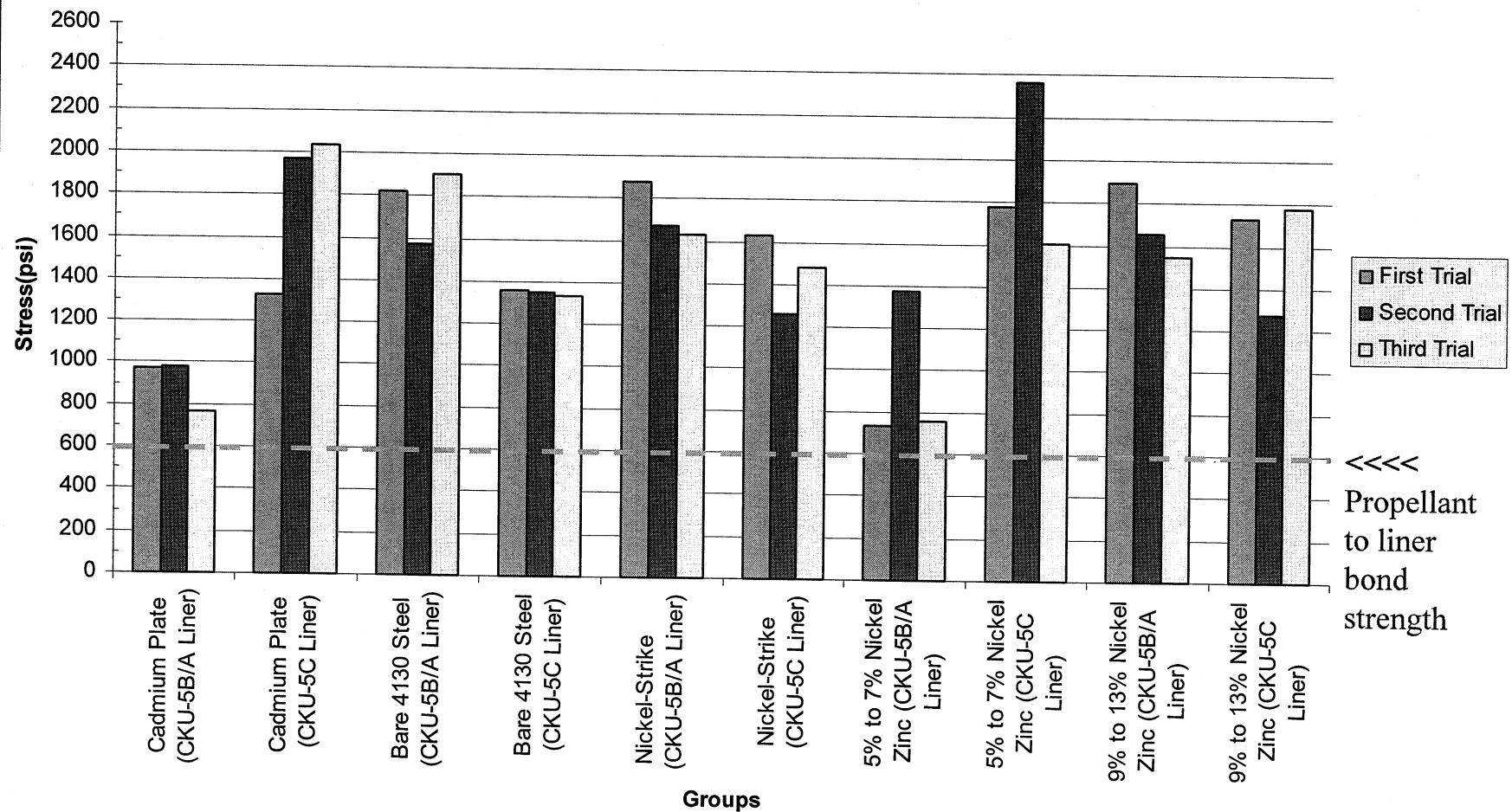
Hydrogen Embrittlement % Results

	Control	Cd Type II, CCC	Zn-12%Ni CCC	Zn-12%Ni PTFE	Zn-6%Ni	
No Stress Relief	N/A	7% (5% max)	16% (5% max)	12% (5% max)	6% (5% max)	
w/ Stress Relief	←No Breakage →					
No Stress Relief			w/ Stress Relief 			

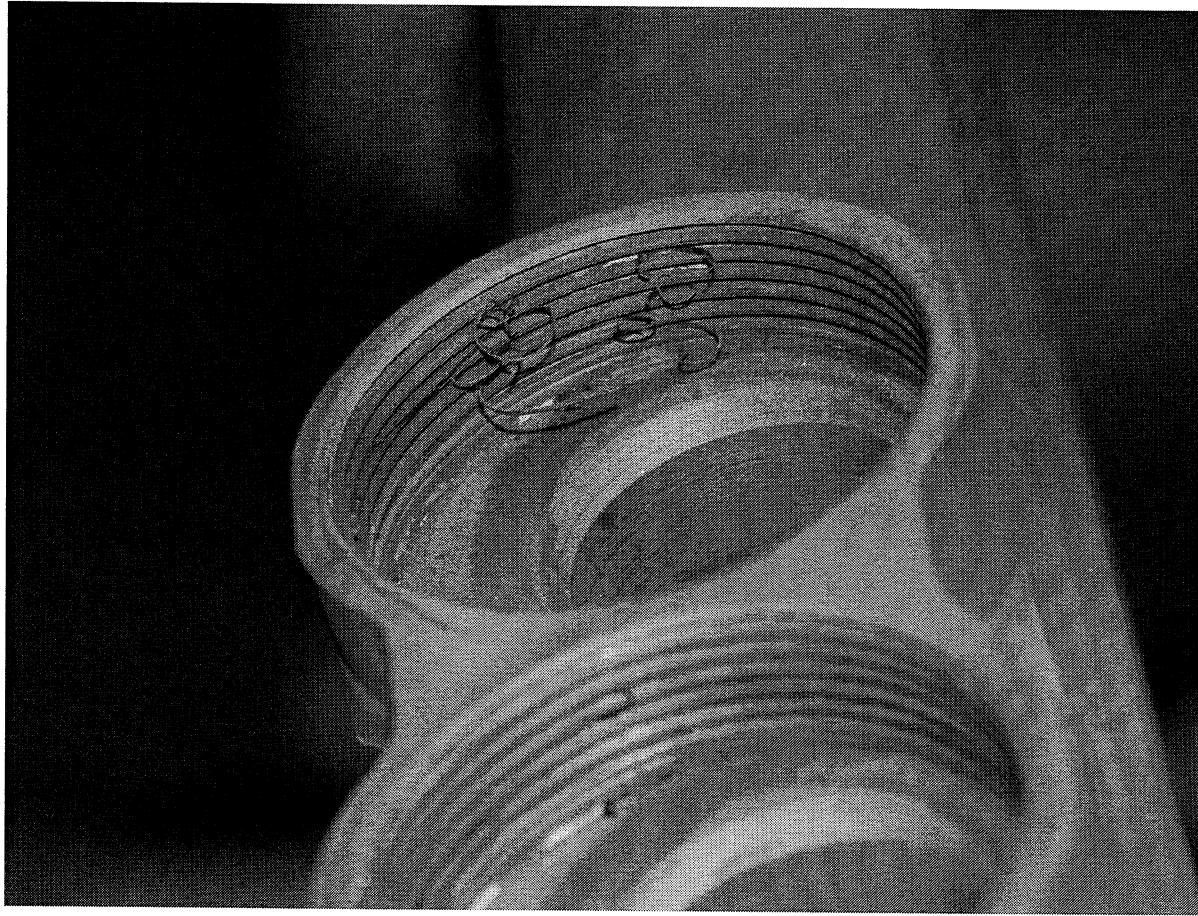
Liner Bond In Tension (BIT) Testing



CKU 5C & 5B/A liner 4340 Steel BIT pull test: three (3) temperature cycles from 165°F to -65°F @ 7 hr. intervals

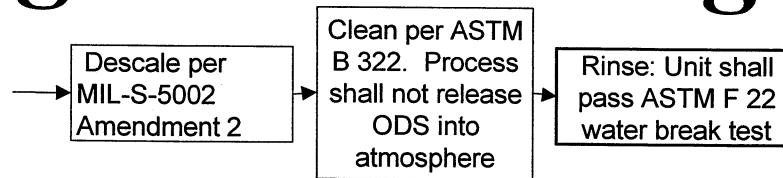


Descaling and Cleaning



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Descaling and Cleaning

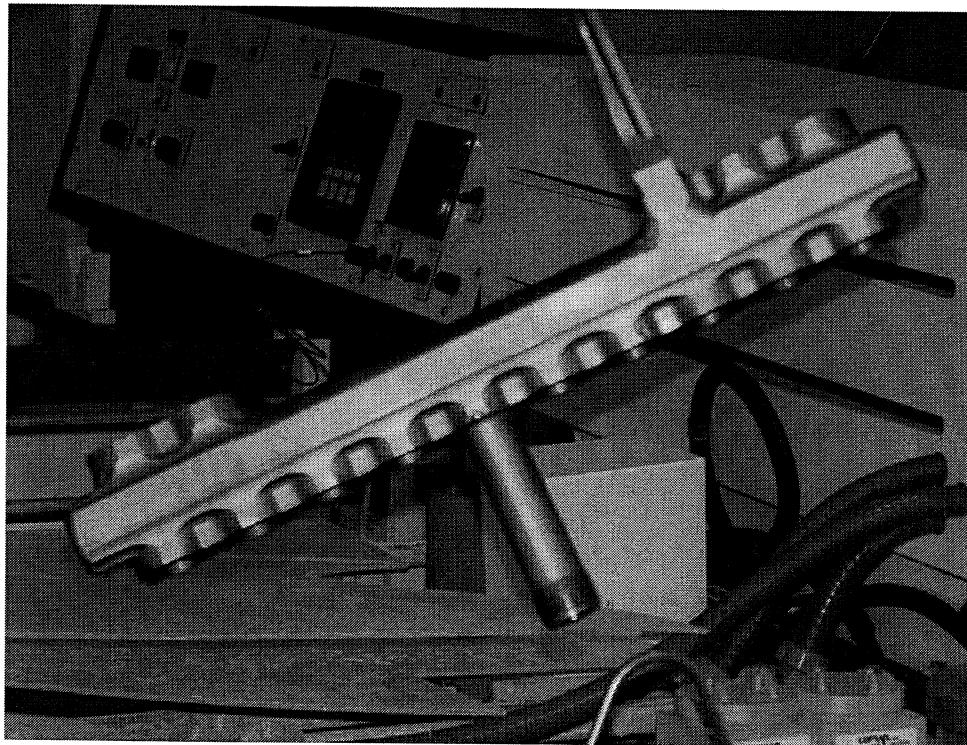


Nickel Strike

Activate surface to receive nickel (i.e., HCL solution)

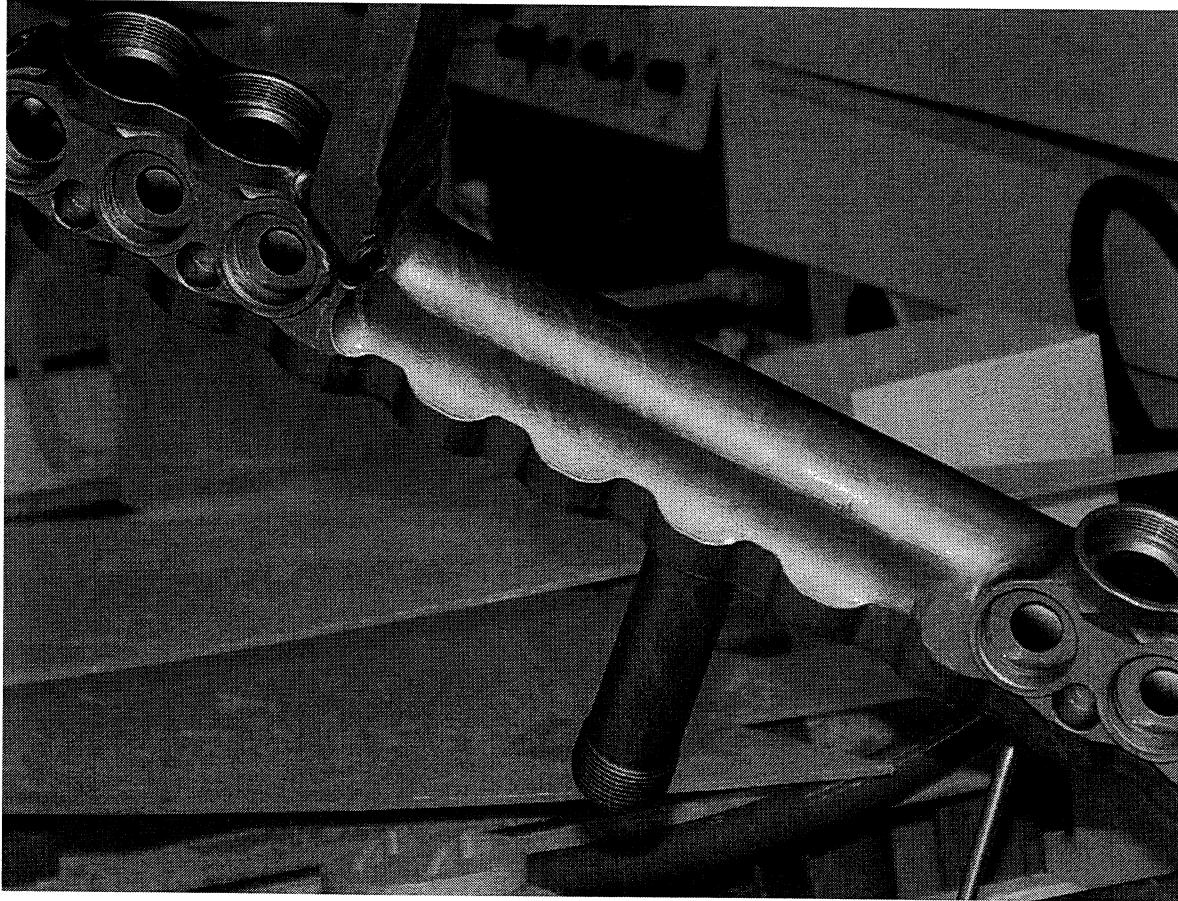
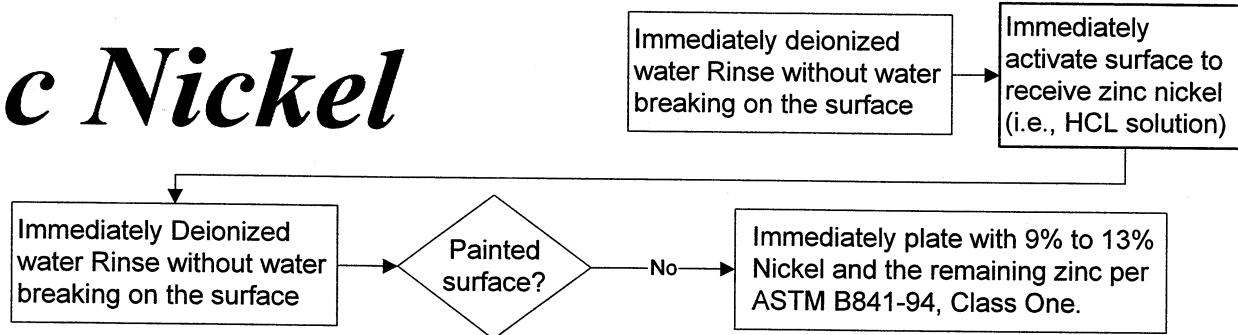
Immediately deionized water rinse without water breaking on the surface

Immediately apply .00005 to .0001 Nickel-Phosphorus coating per ASTM B733-97 Type V, Class one on all surfaces.

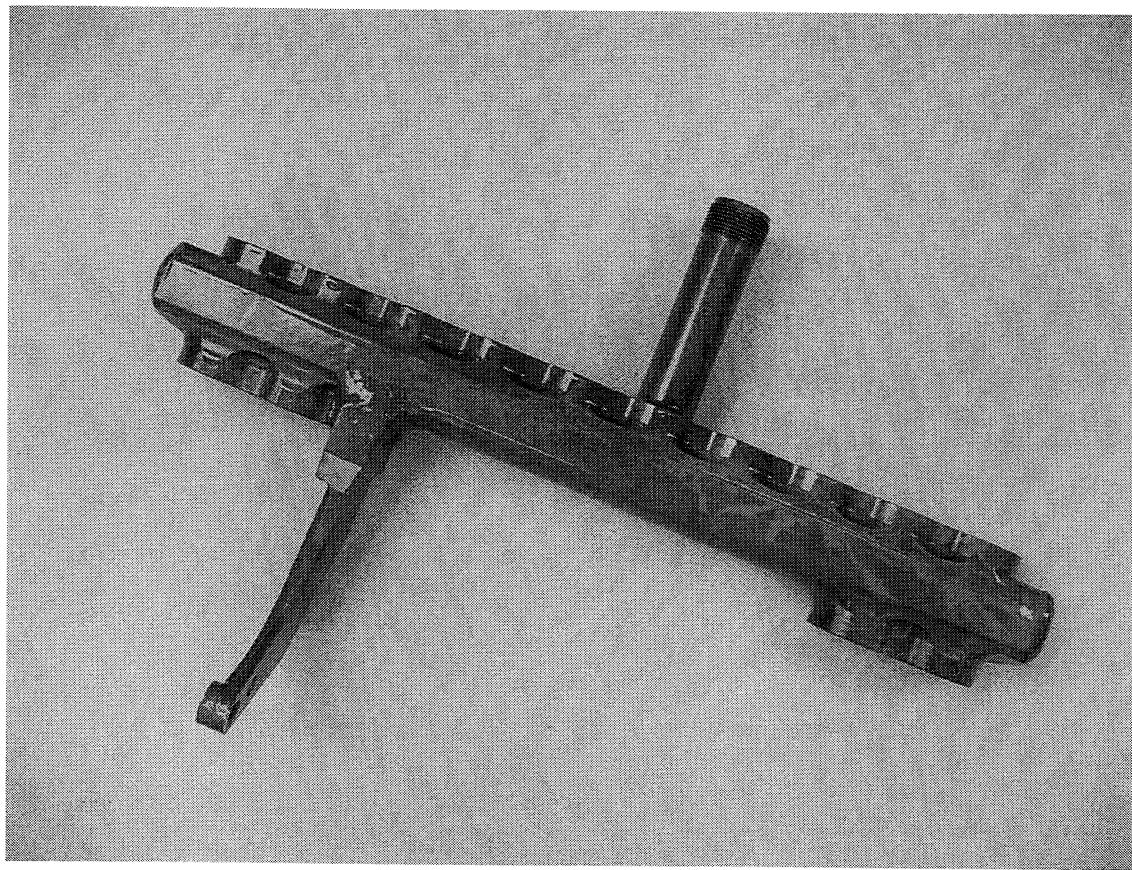
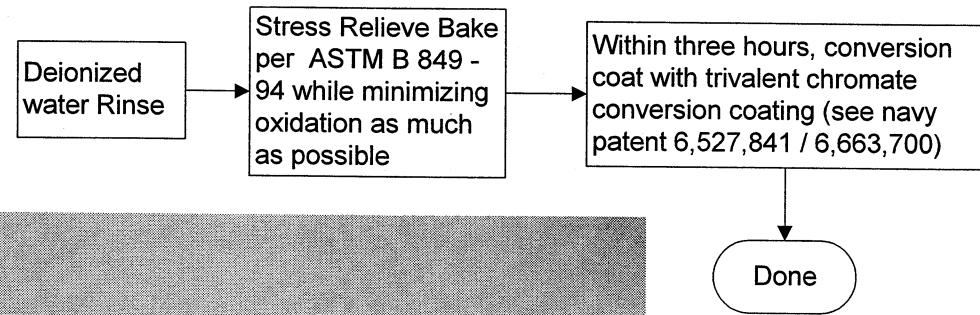


- Minimize oxidation after activating metal surface
- Minimize oxidation of nickel strike surface

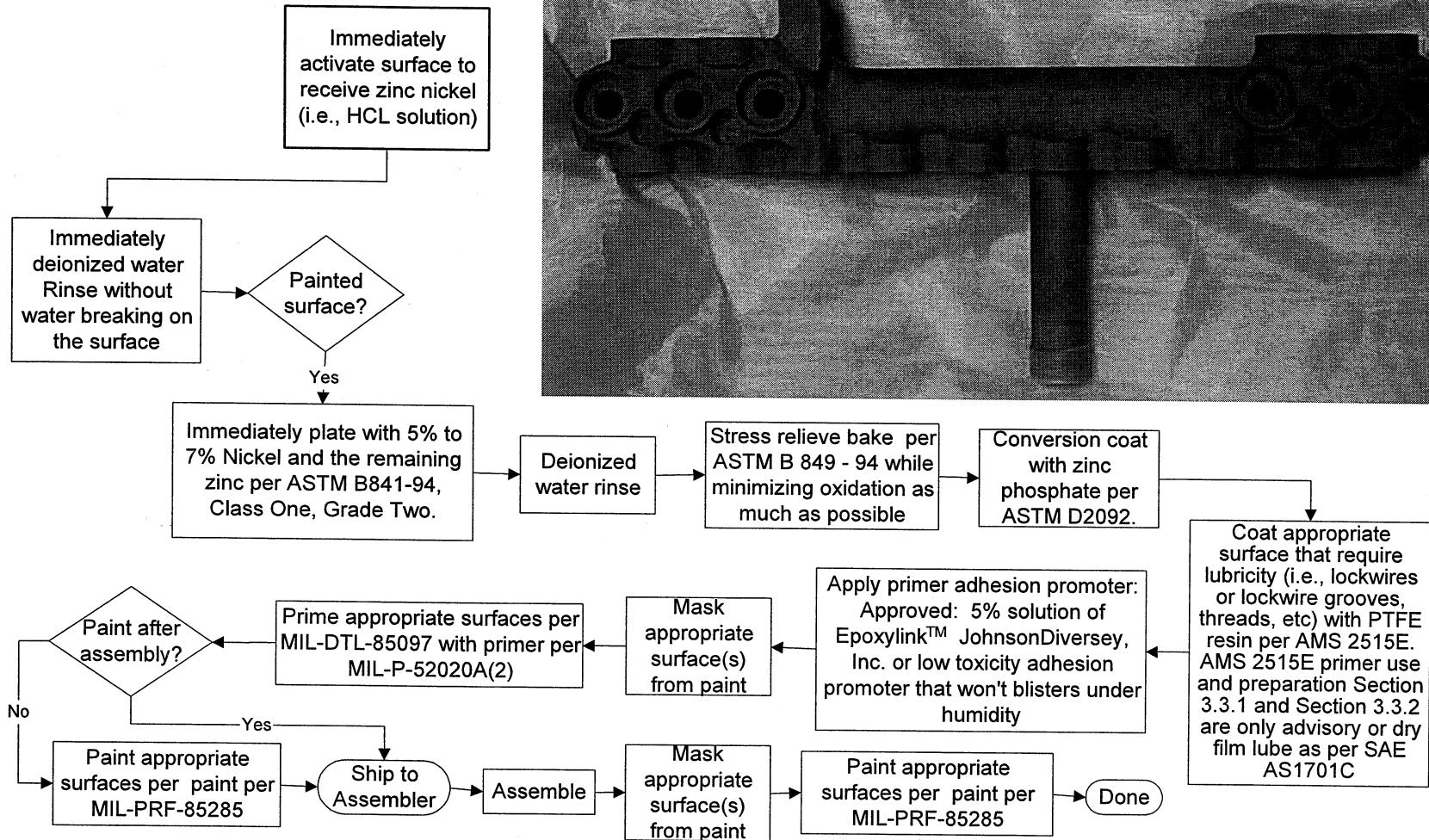
Zinc Nickel



Trivalent Chromate Conversion Coating



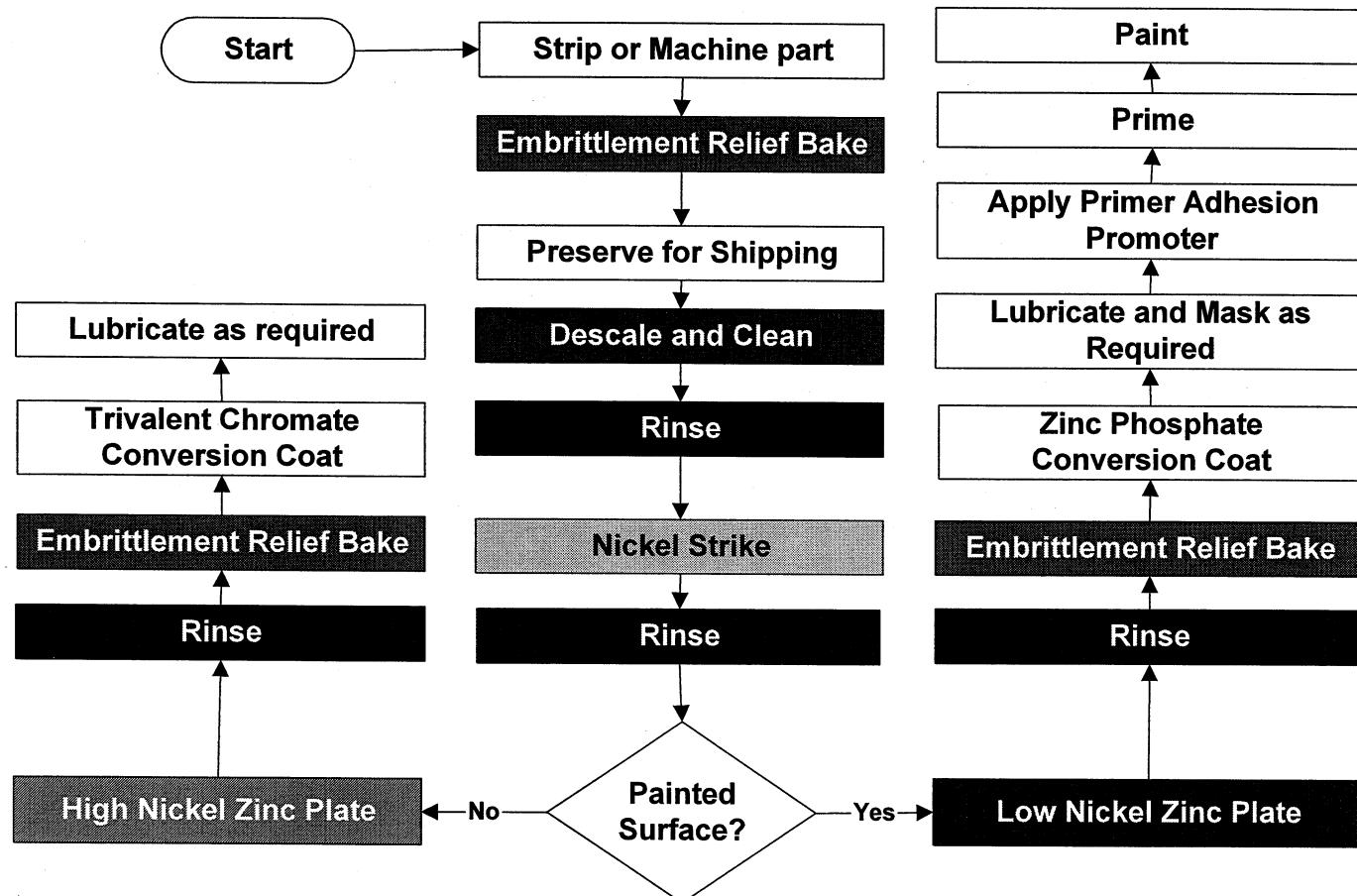
Zinc Phosphate Painted Surfaces



Paint Adhesion Promoter

- Must not contain hexavalent chrome.
- Must promote adhesion between zinc-phosphate and paint primer so that the paint won't blister under humidity.
 - JohnsonDiversey EpoxyLink® adhesion promoter has been qualified by the US army for use on gun barrels.
- Must not significantly reduce corrosion resistance of unprimed/unpainted part.

Zn-Ni Process Summary



Process Advantages

- Consistent part preparation
- Equivalent process for new or reworked parts
- Process different for painted parts

Test Underway

- Low toxicity paint adhesion promoter
- Quick primer application adhesion promoter
- Trivalent conversion coating salt fog testing

2nd Phase Testing Preliminary Results 65 Days Salt Fog



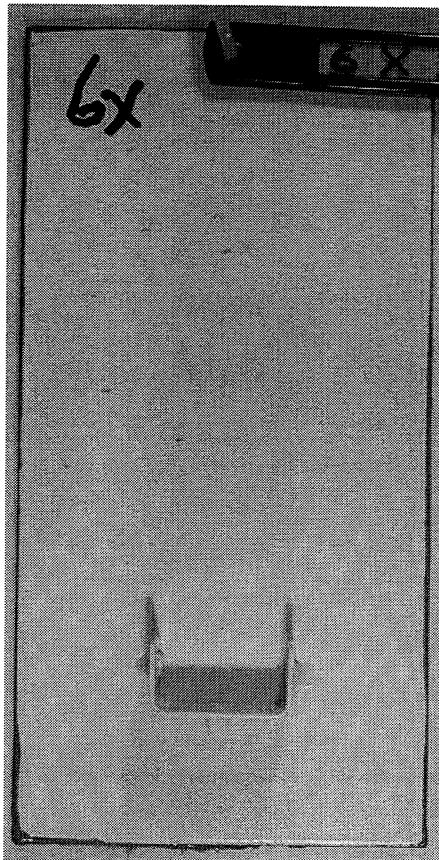
Threaded

Teflon® water based gel
Hex-Chromate Conversion
Zinc-12%Nickel
Nickel Strike

4130/ 4340 Steel

2nd Phase Preliminary Results

65 Days Salt Fog



Naval / Shipboard

Low VOC paint

Low VOC primer in 48 hrs

Phosphate Conversion

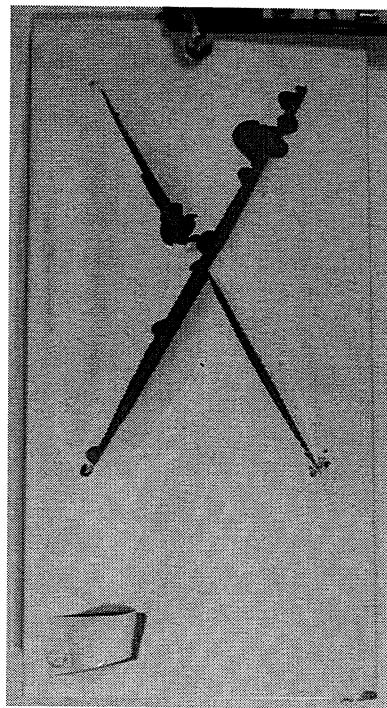
Zinc-5%Nickel

Nickel Strike

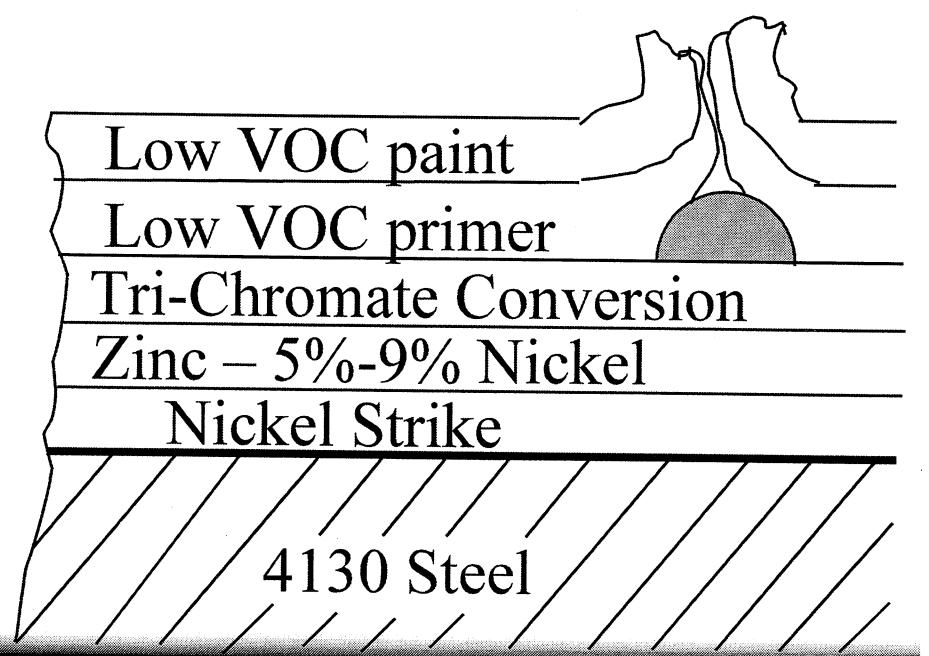
4130 Steel

2nd Phase Preliminary Results

65 Days Salt Fog



Painted



Lessons Learned

- Preparation.
 - Stress relieving before plating is vital to preventing hydrogen embrittlement.
 - Baking after zinc-nickel or cadmium plating is *not* effective in removing hydrogen embrittlement if there is no stress relieving before plating.
- Cleaning.
 - Stress relief oxide is effective in preventing corrosion during temporary storage.
 - Stress relief oxide is effectively removed using a low toxicity descaler.

Lessons Learned (Cont.)

- Nickel strike.
 - Exposure to oxygen must be minimized to assure good zinc-nickel adhesion.
- Conversion coating.
 - Trivalent chromate conversion coating is a viable low toxicity alternative to hexavalent chromate conversion coating.
- Primer adhesion.
 - A primer adhesion promoter or quick priming is vital to prevent blistering on a zinc phosphate conversion coat surface under high moisture.
 - Important to select an adhesion promoter that doesn't significantly reduce zinc phosphate's corrosion protection.

Conclusion

- Upon successful completion of this test program, we should have a qualified non-proprietary replacement surface coating system that doesn't induce hydrogen embrittlement for all of our PAD and most of our CAD items.

Acknowledgement

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- Shawn Blough, CTC
- Jeff Adams, AMZ plating
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